

INDOOR AIR QUALITY ASSESSMENT

**Alcott Elementary School
91 Laurel Street
Concord, Massachusetts**



Prepared by:
Massachusetts Department of Public Health
Bureau of Environmental Health Assessment
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Background/Introduction

At the request of a parent, the Massachusetts Department of Public Health (MDPH), Bureau of Environmental Health Assessment (BEHA) provided assistance and consultation regarding indoor air quality issues and health concerns at the Alcott Elementary School, 91 Laurel Street, Concord, Massachusetts. Concerns about indoor air quality in one wing of the building were the primary focus of concern.

On December 7, 2001, a visit was made to this school by Mike Feeney, Chief of Emergency Response/Indoor Air Quality (ER/IAQ), BEHA, to conduct an indoor air quality assessment. Mr. Feeney was accompanied by Richard Barrett, Director of Maintenance, Concord Public Schools.

The school consisted originally of two buildings; the building that currently houses the kindergarten wing (K wing) and another that currently houses the first through third grade (1-3 wing) (see Attachment 1 for a building diagram). The K wing is a one-story red brick structure built on top of a foundation with a crawlspace. The 1-3 wing is a two-story red brick structure built on a foundation with a crawlspace. The second story rooms exist in a penthouse. Both wings appear to have been built in the same construction period due to design and similarity of configuration of their ventilation systems. A third wing containing third through fifth grade classrooms (3-5 wing) was added to the 1-3 wing. The 3-5 wing is a one-story, red brick structure. Windows in classrooms throughout the school were openable. The heating, ventilating and air-conditioning (HVAC) system does not provide cooling during warm weather.

Over the summer, concerns about fungal growth in classrooms of the 1-3 wing were raised by parents. Carpets were cleaned and disinfected early in the current school

year. An indoor air consulting firm conducted air monitoring for mold and yeast (GE & A, 2001). This sampling effort concluded that airborne fungal concentrations were below detection level and were considered “non-problematic” (GE &A, 2001). Temperature and relative humidity levels were found elevated. Of particular note was that relative humidity levels in the 1-3 wing ranged 1 – 13 percent higher than outdoor relative humidity (73%) at the time of testing (GE & A, 2001). The consultant recommended further monitoring.

Methods

Air tests for carbon dioxide, temperature, and relative humidity were taken with the TSI, Q-Trak TM, IAQ Monitor Model 8551.

Results

This school has a student population of 500 and a staff of over 60. Tests were taken under normal operating conditions and results appear in Tables 1-5.

Discussion

Ventilation

It can be seen from the tables that carbon dioxide levels were elevated above 800 parts per million parts of air (ppm) in seven out of thirty two areas surveyed, which is indicative of adequate ventilation in most areas of the school at the time of testing. Please note that air monitoring was conducted on an unseasonably warm December day (65° F). Windows (particularly K wing) were open, which can greatly reduce carbon

dioxide levels. Prior to student/school dismissal, a second round of air monitoring was conducted in the 1-3 wing to establish possible changes in carbon dioxide due to prolonged occupancy of these classrooms. All classrooms had carbon dioxide level below 800 ppm with windows closed, indicating an adequate supply of fresh air from the ventilation system.

Fresh air is supplied to the 1-3 wing and K wing classrooms by cabinet mounted fresh air diffusers (see Picture 1) that are connected by ductwork to an air handling unit (AHU) in the crawlspace (see Figure 1). All fresh air diffusers were ejecting air during this assessment. In most classrooms, however, these vents were blocked with paper, boxes, books and other obstructions. In order for these vents to provide air, they must remain clear of obstructions.

Exhaust ventilation in the 1-3 and K wings is provided by a grill located in sink cabinets (see Picture 2). These grills are also connected to the crawlspace AHU by ductwork. All exhaust vents in these wings were drawing air during the assessment.

Fresh air for the 3-5 wing is supplied by a mechanical unit ventilator (univent) system. Univents draw air from outdoors through a fresh air intake located on the exterior walls of the building and return air through an air intake located at the base of each unit. The mixture of fresh and return air is drawn through a filter and a heating coil, and is then expelled from the univent by motorized fans through fresh air diffusers located at the top of each unit (see [Figure 2](#)). Univents were operating in all classrooms surveyed during the assessment. Obstructions to airflow, such as objects stored on or in front of univents, were observed in a number of classrooms. In order for univents to

function as designed, fresh air diffusers and return vents must be unblocked and remain free of obstructions.

Exhaust ventilation in the 3-5 wing classrooms is provided by a mechanical exhaust system. The exhaust vents are located in the upper portions of coat closets in classrooms. Classroom air is drawn through a space beneath the closet door and out the exhaust vent at the top of the closet. This design allows for the vents to be easily blocked by stored materials on shelves beneath the exhaust vent. In a number of classrooms, vents were blocked with books, book bags, boxes and other obstructions. An exhaust vent motor located on the roof was found to be operating.

To maximize air exchange, the BEHA recommends that both supply and exhaust ventilation operate continuously during periods of school occupancy. In order to have proper ventilation with a mechanical supply and exhaust system, the systems must be balanced to provide an adequate amount of fresh air to the interior of a room while removing stale air from the room. The date of the last balancing was not available at the time of the assessment. It is recommended that existing ventilation systems be re-balanced every five years to ensure adequate air systems function (SMACNA, 1994).

The Massachusetts Building Code requires a minimum ventilation rate of 15 cubic feet per minute (cfm) per occupant of fresh outside air or have openable windows in each room. The ventilation must be on at all times that the room is occupied. Providing adequate fresh air ventilation with open windows and maintaining the temperature in the comfort range during the cold weather season is impractical. Mechanical ventilation is usually required to provide adequate fresh air ventilation.

Carbon dioxide is not a problem in and of itself. It is used as an indicator of the adequacy of the fresh air ventilation. As carbon dioxide levels rise, it indicates that the ventilating system is malfunctioning or the design occupancy of the room is being exceeded. When this happens a buildup of common indoor air pollutants can occur, leading to discomfort or health complaints. The Occupational Safety and Health Administration (OSHA) standard for carbon dioxide is 5,000 parts per million parts of air (ppm). Workers may be exposed to this level for 40 hours/week, based on a time weighted average (OSHA, 1997).

The Department of Public Health uses a guideline of 800 ppm for publicly occupied buildings. A guideline of 600 ppm or less is preferred in schools due to the fact that the majority of occupants are young and considered to be a more sensitive population in the evaluation of environmental health status. Inadequate ventilation and/or elevated temperatures are major causes of complaints such as respiratory, eye, nose and throat irritation, lethargy and headaches.

Temperature readings were in a range of 69° F to 78° F, which were very close to the BEHA recommended range for comfort. The BEHA recommends that indoor air temperatures be maintained in a range between 70° F to 78° F in order to provide for the comfort of building occupants. In many cases concerning indoor air quality, fluctuations of temperature in occupied spaces are typically experienced, even in a building with an adequate fresh air supply.

The relative humidity ranged from 27 to 33 percent in the 3-5 wing and 26 to 33 percent in the K wing. These relative humidity measurements were below the BEHA recommended comfort range. The BEHA recommends a comfort range of 40 to 60

percent for indoor air relative humidity. Relative humidity in the building would be expected to drop below comfort levels during the winter months due to heating. The sensation of dryness and irritation is common in a low relative humidity environment. Low relative humidity is a common problem during the heating season in the northeast part of the United States.

However, relative humidity levels measured in the 1-3 wing by BEHA staff and GE & A would indicate that an unusual source of water vapor exists in this structure. It is important to note that relative humidity measured in the 1-3 wing during the morning round of BEHA air sampling ranged from 33 to 49 percent. These relative humidity measurements were in excess of both the 3-5 wing and K wing measurements (1-18 %) as well as outdoor morning measurements (13-29 %). In order to ascertain whether relative humidity measurements in the 1-3 wing were likely to be chronically above outdoor levels, air monitoring was conducted in these classrooms in the afternoon. Relative humidity levels measured in the afternoon were 9-15% higher than outdoor relative humidity (23%). This type of increase in relative humidity usually indicates that the exhaust system is not operating sufficiently to remove normal indoor air pollutants (e.g., water vapor from respiration). Moisture removal is important since the sensation of heat conditions increase as relative humidity increases (the relationship between temperature and relative humidity is called the heat index). As indoor temperature rises, the addition of more relative humidity will make occupants feel hotter. If moisture is removed, the comfort of individuals is enhanced. In this instance, the carbon dioxide levels measured in the 1-3 wing classrooms indicate that adequate fresh air and exhaust ventilation exists, therefore poor ventilation is unlikely to be the sole cause of elevated

relative humidity. The relative humidity measurements in occupied space of the 1-3 wing indicate that some source of water vapor, aside from the occupant respiration, exists within the wing.

Microbial/Moisture Concerns

In an effort to identify the source of water vapor elevating the relative humidity in the 1-3 wing, BEHA staff entered the crawlspace of the 1-3 wing. Afternoon relative humidity measured near the entrance of the 1-3-wing crawlspace was 43 percent, which was 3 to 11 percent greater than the relative humidity measured in the occupied areas of 1-3 wing. This measurement, in combination with the 1-3 wing relative humidity testing results, indicates that a source of water vapor exists in the crawlspace. There are several conditions that may provide a source of water vapor in the crawlspace:

1. Rainwater from the roof of the building is directed into a downspout system that empties onto a tarmac apron surrounding the exterior wall of this wing. The tarmac apron appears to be sloped *towards* the foundation (see Picture 3), allowing rainwater to come into contact with the exterior wall tarmac junction. Over time, this process can undermine the integrity of the building envelope and provide a means of water entry into the building through capillary action through foundation concrete and masonry (Lstiburek & Brennan, 2001). This condition may also allow for water to gather beneath the crawlspace floor. This condition does not exist in the 3-5 wing. The tarmac apron surrounding the 3-5 wing is sloped away from the exterior walls

of the wing, which prevents water pooling. Building occupants report that the 1-3 wing tarmac is prone to icing during the winter.

2. An examination of the crawlspace floor revealed a narrow, 20+ feet long trench in the concrete floor (see Picture 4). This trench, of unknown origin or purpose, was dirt filled and extended to the north foundation. In an effort to determine whether this trench was a source of moisture, Concord Public School (CPS) staff covered part of this trench with plastic. The side of the plastic facing the trench was heavily coated with water droplets, indicating that this trench is a moisture source (see Picture 5)
3. CPS staff reported that steam pipes exist in the crawlspace. Leaking of these pipes may also serve as a water vapor source. This is unlikely to be the source of water vapor wetting carpets over the summer however, since the heating system would be deactivated.
4. Another possible contributing factor to water vapor penetration is through kindergarten exterior doors. A space in the doorframe exists, through which outdoor light could be seen (see Picture 6).

Of note is the configuration of the foundation walls of this wing. Crawlspace foundation walls are customarily equipped with passive air vents to allow for air movement into the space. The 103 wing has no crawlspace vents. This condition may allow for water vapor to accumulate and either penetrate into occupied areas through spaces around utility/heating pipes or other floor penetrations or to be drawn into the return air ducts through spaces in the sheet metal. Return air vents are depressurized, which would serve to draw crawlspace air into the duct air stream. Water vapor may then

be recirculated into classrooms by the AHU. If this condition exists, operation of the AHU during the summer months can serve to increase relative humidity inside the 1-3 wing, resulting in the wetting of carpeting.

Prolonged indoor relative humidity concentrations above 70 percent can foster mold growth in susceptible materials (ASHRAE, 1989) such as carpeting, cardboard, paper, books, cloth and other materials. These materials, if repeatedly exposed to high humidity, can serve as mold growth media. The American Conference of Governmental Industrial Hygienists (ACGIH) recommends that carpeting be dried with fans and heating within 24 hours of becoming wet (ACGIH, 1989). If carpets are not dried within this time frame, mold growth may occur. Water-damaged carpeting cannot be adequately cleaned to remove mold growth. The application of a mildewcide to moldy carpeting is not recommended. Please note that the carpet cannot be readily removed due to the asbestos content of the tile beneath the carpet. *If carpet is removed, all relevant containment precautions to prevent the aerosolization of asbestos from the floor tiles must be taken.*

Another potential source of mold and spores are plants located throughout the building. Plant soil, standing water and drip pans can serve as media for mold growth. Drip pans should be inspected periodically for mold growth. Over watering of plants should be avoided. Many plants are located on, above, and around fresh air diffusers. Plants should be located away from air diffusers to prevent dust, mold spores and pollen from being drawn into fan coils and distributed throughout a room.

Other Concerns

Several other conditions were noted during the assessment, which can affect indoor air quality. Excessive chalk dust was observed in some classrooms. Chalk dust can be a respiratory irritant if aerosolized. Moreover, a variety of items were seen piled on windowsills, tabletops, counters, bookcases and desks in offices and cubicle areas. The large amount of items stored provides a means for dusts, dirt and other potential respiratory irritants to accumulate. These stored items, (e.g., papers, folders, boxes) also make it difficult for custodial staff to clean. Dust can be irritating to the eyes, nose and respiratory tract.

Of note is the use of different volatile organic compound (VOC) containing products in the building. A number of products were found in classrooms. Rubber cement contains n-hexane or heptane, which can be irritating to the eyes, nose and throat; in addition n-hexane is an extremely flammable material. Local exhaust ventilation should be utilized when this material is used. Other VOC containing products, such as permanent markers, dry erase markers, liquid correction fluid, and furniture polish (Gosselin, R.E., Smith, R.P., Hodge, H.C, 1984) were also found in classrooms. Under the Labeling of Hazardous Art Materials Act (LHAMA), art supplies containing hazardous materials that can cause chronic health effects must be labeled as required by federal law (USC, 1988). The use of these materials should be limited to times when students are not present and only when adequate exhaust ventilation is available.

Conclusions/Recommendations

As indicated by air monitoring, a source of water vapor exists in the 1-3 wing crawlspace that may be contributing to conditions that created sufficient moisture in occupied areas of the building to allow for microbial growth in classroom carpeting. While cleaning carpeting may help remove some microbiological contamination, this problem would be expected to reoccur during increased precipitation and prolonged hot, humid weather. As noted previously, any removal of carpeting would require asbestos removal/containment regulations to be observed. In addition, removal of carpeting from the 1-3 wing classrooms does not eliminate the excess relative humidity problem. For these reasons a two-phase approach is required, consisting of immediate (**short-term**) measures to improve air quality at the school and **long-term** measures that will require planning and resources to adequately address overall indoor air quality concerns.

The following **short-term** measures should be considered for immediate implementation:

1. Render holes through the 1-3 wing floor airtight with a sealant compound.
2. Seal each joint on the return ducts in the crawlspace to prevent crawlspace air and moisture entrainment. Be sure ***not*** to use duct tape. Use duct mastic to permanently seal duct joints. Duct tapes tend to lose adherence and should only be used as an interim/emergency measure.
3. Identify the purpose of the trench in the 1-3 wing crawlspace floor. If no purpose is identified for the trench, seal it with appropriate materials that will adhere to existing floor materials. If purpose is identified, use appropriate methods to minimize water penetration.

4. Examine pipes in 1-3 wing crawlspace for steam pipe leaks and repair if leaks are present.
5. Render classroom exterior doors airtight by eliminating spaces between doors and frames.
6. Discontinue wet cleaning of carpeting to prevent further mold growth unless necessary. Evaluate carpeting in other classrooms for mold growth and consider removing carpet in a manner consistent with asbestos remediation laws and regulations.
7. Examine records to ascertain the latest date of ventilation system balancing. If more than five years, consider consulting a ventilation engineer to re-balance the ventilation system.
8. Acquire current Material Safety Data Sheets for all products containing hazardous materials that are used within the building, including office supplies, in conformance with the Massachusetts Right-To-Know Law, M.G.L. c. 111F (MGL, 1983).
9. Consider replacing art and school supplies containing materials that require labeling under the Labeling of Hazardous Art Materials Act (LHAMA) with water-based materials, to reduce VOCs in classrooms.
10. For buildings in New England, periods of low relative humidity during the winter are often unavoidable. Therefore, scrupulous cleaning practices should be adopted to minimize common indoor air contaminants whose irritant effects can be enhanced when the relative humidity is low. To control for dusts, a high efficiency particulate arrestance (HEPA) filter equipped vacuum cleaner in conjunction with wet wiping of all surfaces is recommended. Avoid the use of

feather dusters. Drinking water during the day can help ease some symptoms associated with a dry environment (throat and sinus irritations).

11. Move plants away from fresh air diffusers in classrooms. Ensure plants have drip pans. Examine drip pans periodically for mold growth and disinfect with an appropriate antimicrobial where necessary. Consider reducing the number of plants in this building.
12. Clean chalkboards and chalk trays regularly to prevent the build-up of excessive chalk dust.

The following **long-term measures** should be considered:

1. Examine the feasibility of re-paving the tarmac apron around the 1-3 wing to have it slope away from the edge of the building in a manner similar to the 3-5 wing tarmac apron. Once done, apply an appropriate sealant to the seam between the tarmac and building exterior wall.
2. Consideration should be given to extending the downspouts in a manner to empty rainwater at least 5 feet from the foundation wall to prevent water entrainment.
3. School officials report plans to remove carpets from the 1-3 wing. As discussed during the visit, caution should be taken when removing carpeting in this section of the building, since it is adhered to asbestos containing floor tile. All relevant asbestos containment procedures mandated by Massachusetts and federal laws and regulations should be followed when removing this carpet. Consideration should be given to removing the entire carpet. MDPH supports plans to remove carpet from the 1-3 wing over the next summer vacation to eliminate the possibility of occupant exposure to either asbestos fibers or mold spores.

References

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SMACNA. 1994. HVAC Systems Commissioning Manual. 1st ed. Sheet Metal and Air Conditioning Contractors' National Association, Inc., Chantilly, VA.

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Attachement 1
Layout of Alcott Elementary School

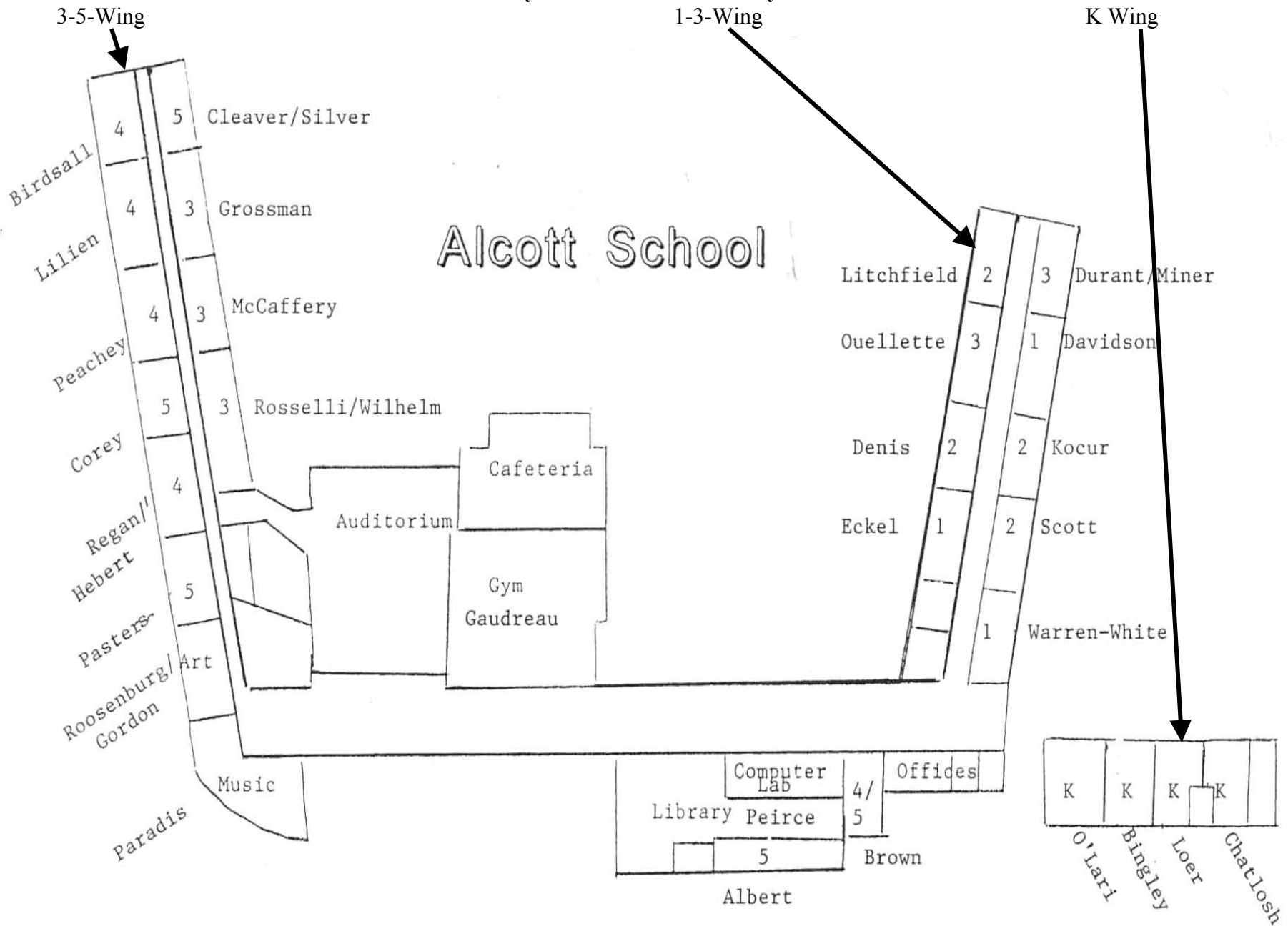


Figure 1
Probable Configuration of Airflow in 1-3 Wing and K Wing

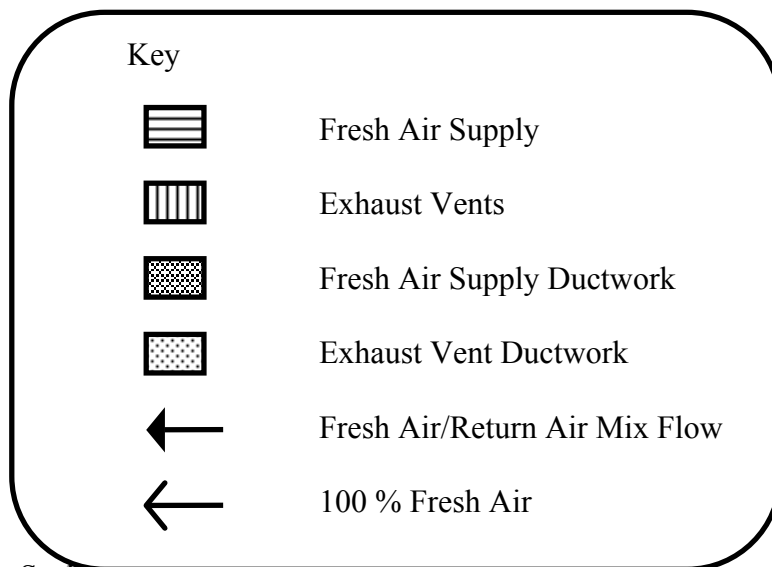
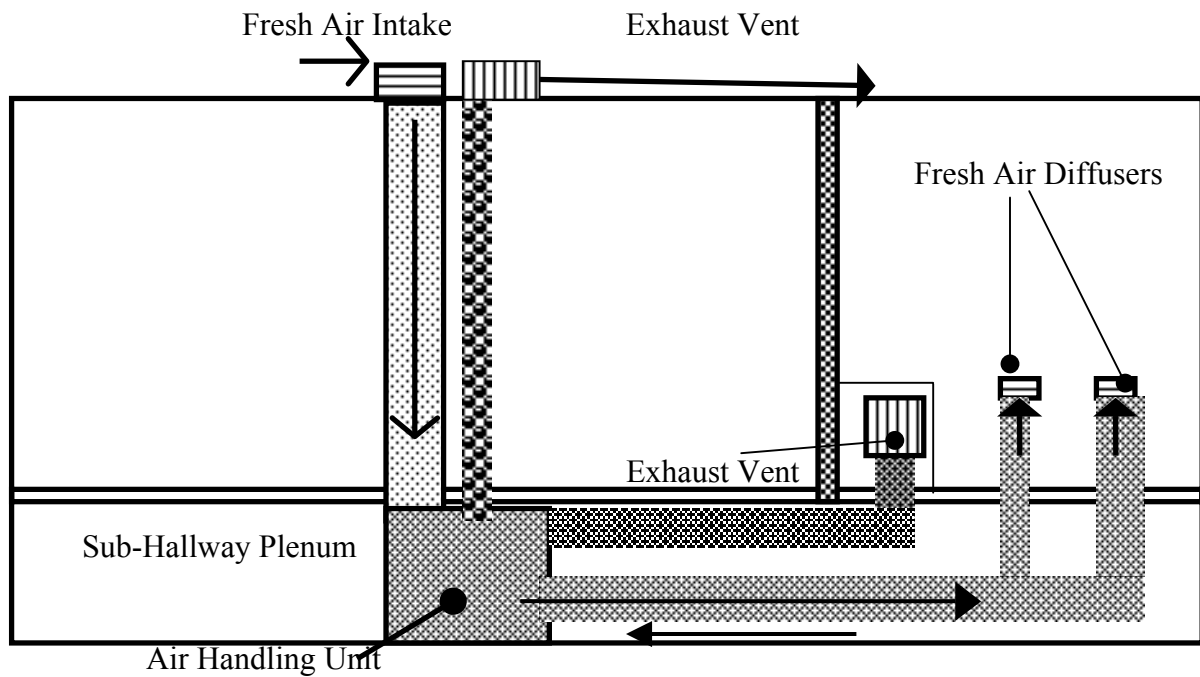
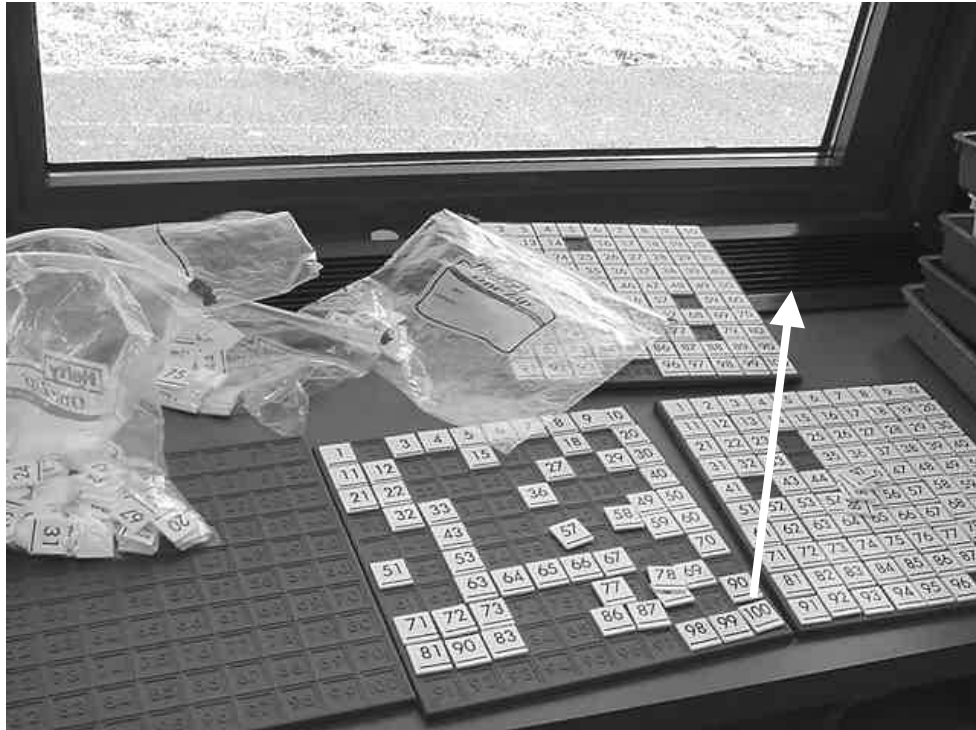


Figure Not to Scale

Picture 1



Fresh Air Supply Vents Typical Of the 1-3 And K Wings

Picture 2



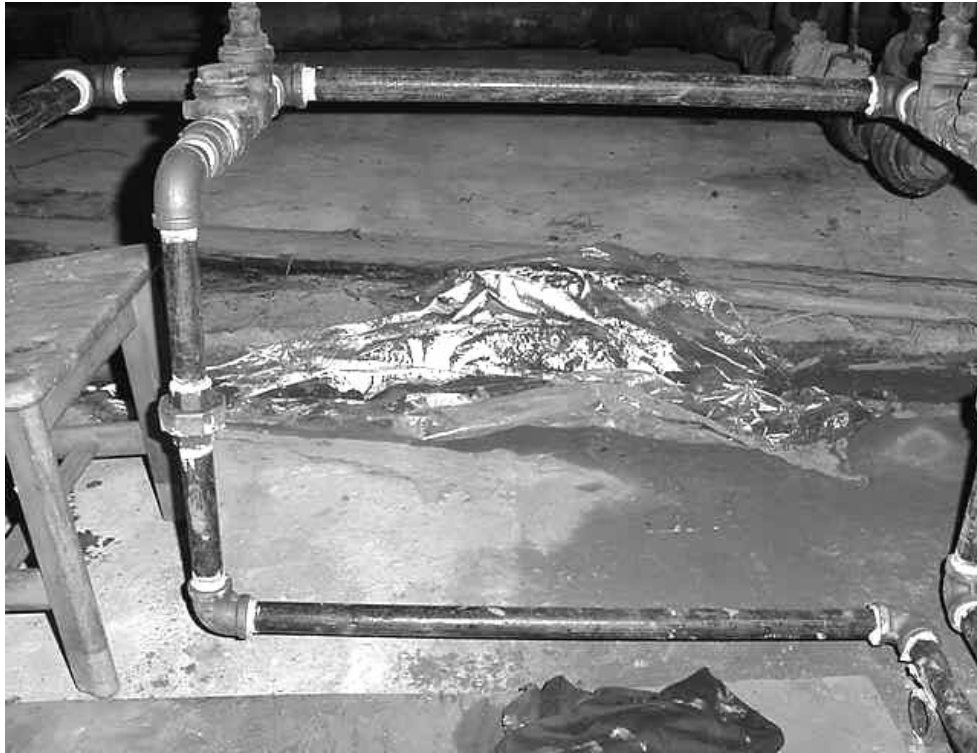
Exhaust Vents Typical Of the 1-3 Wing

Picture 3



Tarmac Apron around 1-3-Wing, Note Location of Downspout Termini at Base of Building

Picture 4



Trench In 1-3-Wing Crawlspace Floor

Picture 5



Plastic Covering the Trench in Picture 4, Note Beaded Water

Picture 6



Space Beneath Classroom Exterior Door, Note Light

TABLE 1

Indoor Air Test Results – Alcott Elementary School, Concord, MA – December 7, 2001

Location	Carbon Dioxide *ppm	Temp. °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation		Remarks
						Intake	Exhaust	
Outside (Background)	377	69	20					AM
Room 8	660	70	49	19	Yes	Yes	Yes	Plants, 2 water damaged CT, door open,
Main Office	492	71	27	2	Yes	No	No	Window mounted A/C, window open
Room 9	631	73	43	22	Yes	Yes	Yes	
Room 7	645	73	43	19	Yes	Yes	Yes	Supply vent blocked, door open
Room 10	629	68	44	16	Yes	Yes	Yes	Supply blocked by paper, air-to-air exchange
Room 6	626	69	43	18	Yes	Yes	Yes	Plant/cardboard on supply, clutter, door open
Room 11	675	73	37	21	Yes	Yes	Yes	Clutter/plants on supply, window and door open, chalk dust
Room 5	778	75	41	19	Yes	Yes	Yes	Plants-box, rubber cement & heptane
Room 12	709	74	35	20	Yes	Yes	Yes	Plastic on supply, furniture polish
Room 4	688	73	33	16	Yes	Yes	Yes	Rubber cement

* ppm = parts per million parts of air
CT = ceiling tiles

Comfort Guidelines

Carbon Dioxide - < 600 ppm = preferred
600 - 800 ppm = acceptable
> 800 ppm = indicative of ventilation problems
Temperature - 70 - 78 °F
Relative Humidity - 40 - 60%

TABLE 2

Indoor Air Test Results – Alcott Elementary School, Concord, MA – December 7, 2001

Location	Carbon Dioxide *ppm	Temp. °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation		Remarks
						Intake	Exhaust	
Room 20	602	72	26	0	Yes	Yes	Yes	Space under exterior door, plants, dry erase board, door open
Room 19	525	72	26	1	Yes	Yes	Yes	Plants, dry erase board, door open
Room 18	818	72	26	19	Yes	Yes	Yes	Cleaning products, dry erase board, door open
Room 21	761	74	26	19	Yes	Yes	Yes	Plant, dry erase board, door open
Room 17	414	69	27	3	Yes	Yes	Yes	Board blocking supply, cabinet blocking exhaust
Room 23	386	71	25	0	Yes	Yes	Yes	Window and door open, dry erase board
Room 16	656	72	27	21	Yes	Yes	Yes	Space - exterior door
Room 15	959	70	30	20	Yes	Yes	Yes	Window and door open, space - exterior door
Room 14	774	73	31	20	Yes	Yes	Yes	Supply blocked, dry erase board, door open
Room 13	966	72	30	19	Yes	Yes	Yes	Boxes blocking exhaust, paper and misc. items blocking supply, dry erase board, kiln
Music Room	1168	74	33	24	Yes	Yes	Yes	Door open

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TABLE 3

Indoor Air Test Results – Alcott Elementary School, Concord, MA – December 7, 2001

Location	Carbon Dioxide *ppm	Temp. °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation		Remarks
						Intake	Exhaust	
Photocopier Room	761	75	28	2		No	Yes	2 photocopiers, passive door vent
KEE	833	73	33	21	Yes	Yes	Yes	Window open
KEN	496	74	27	18	Yes	Yes	Yes	Window open
KWM	411	72	26	0	Yes	Yes	Yes	Window and 2 exterior doors open
KWW	592	73	28	16	Yes	Yes	Yes	Window open, book blocking supply
Library	568	74	26	20+	Yes	Yes	Yes	Door open
Cafeteria	790	75	25	50+	Yes	Yes	Yes	
Gym	595	77	25	0	Yes	Yes	Yes	
Interior Classroom	593	76	27	0	Yes	No	Yes	Dry erase board, door open
Computer Lab	1340	78	32	17	Yes		Yes	Passive door vent, 14 computers
Outdoors/ Background	378	65	23					PM

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TABLE 4

Indoor Air Test Results – Alcott Elementary School, Concord, MA – December 7, 2001

Location	Carbon Dioxide *ppm	Temp. °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation		Remarks
						Intake	Exhaust	
Crawlspace	508	77	43					
Room 8	546	73	34	1	Yes	Yes	Yes	Door open
Hallway (at room 8)	591	73	34	0	Yes	Yes	Yes	Door open
Room 9	475	69	38	0	Yes	Yes	Yes	Door open
Room 7	483	72	38	0	Yes	Yes	Yes	Door open
Room 10	553	72	37	21	Yes	Yes	Yes	Door open
Room 6	523	73	36	2	Yes	Yes	Yes	Door open
Room 11	688	73	36	19	Yes	Yes	Yes	
Room 5	645	74	36	18	Yes	Yes	Yes	
Room 12	799	75	36	26	Yes	Yes	Yes	
Room 4	577	74	32	1	Yes	Yes	Yes	

* ppm = parts per million parts of air
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Comfort Guidelines

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> 800 ppm = indicative of ventilation problems
Temperature - 70 - 78 °F
Relative Humidity - 40 - 60%

TABLE 5

Indoor Air Test Results – Alcott Elementary School, Concord, MA – December 7, 2001

Location	Carbon Dioxide *ppm	Temp. °F	Relative Humidity %	Occupants in Room	Windows Openable	Ventilation		Remarks
						Intake	Exhaust	
Teacher's Lounge	823	73	29	2				

Comfort Guidelines

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> 800 ppm = indicative of ventilation problems
Temperature - 70 - 78 °F
Relative Humidity - 40 - 60%